APPENDIX 3.2

HAZUS 500 Year Probabilistic Earthquake run

Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Earthquake

In order to determine structures that are vulnerable and estimated to be damaged during an earthquake, the Project Staff used an enhanced HAZUS MH-MR4 run. GIS Staff was able to incorporate new soil data into HAZUS and complete a level 2 analysis for earthquake.

The HAZUS earthquake scenario used was a “Probabilistic 500 Year Earthquake". The HAZUS results show the following estimates:

- About 3,382 buildings will be at least moderately damaged. This is over 1.00% of the total number of buildings in the region.
- Structural loss estimate is $212,530,000.
- An estimated 40 buildings will be damaged beyond repair.

HAZUS-MH: Earthquake Event Report

Region Name: JeffersonCountyEarthquake

Earthquake Scenario: 500YearProbabilisticEvent

Print Date: February 14, 2011

Totals only reflect data for those census tracts/blocks included in the user's study region.

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

HAZUS is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of HAZUS is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

Kentucky

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 398.21 square miles and contains 170 census tracts. There are over 287 thousand households in the region and has a total population of 693,604 people (2000 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 271 thousand buildings in the region with a total building replacement value (excluding contents) of 65,238 (millions of dollars). Approximately 91.00 % of the buildings (and 70.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 5,208 and 3,130 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 271 thousand buildings in the region which have an aggregate total replacement value of 65,238 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 79% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilities into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 15 hospitals in the region with a total bed capacity of 3,596 beds. There are 271 schools, 25 fire stations, 32 police stations and 0 emergency operation facilities. With respect to HPL facilities, there are 29 dams identified within the region. Of these, 9 of the dams are classified as 'high hazard'. The inventory also includes 445 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 8,338.00 (millions of dollars). This inventory includes over 522 kilometers of highways, 375 bridges, 10,644 kilometers of pipes.

Table 1: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	375	1,035.20
	Segments	336	3,626.40
	Tunnels	2	2.90
	Subtotal		4,664.50
Railways	Bridges	15	1.70
	Facilities	17	45.30
	Segments	143	208.50
	Tunnels	0	0.00
	Subtotal		255.50
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
	Subtotal		0.00
Bus	Facilities	3	3.20
	Subtotal		3.20
Ferry	Facilities	0	0.00
	Subtotal		0.00
Port	Facilities	37	73.90
	Subtotal		73.90
Airport	Facilities	2	21.30
	Runways	5	189.80
	Subtotal		211.10
	Total		5,208.20

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	106.40
	Facilities	7	228.40
	Pipelines	0	0.00
	Subtotal		334.90
Waste Water	Distribution Lines	NA	63.90
	Facilities	18	1,174.80
	Pipelines	0	0.00
	Subtotal		1,238.70
Natural Gas	Distribution Lines	NA	42.60
	Facilities	1	1.10
	Pipelines	0	0.00
	Subtotal		43.60
Oil Systems	Facilities	4	0.40
	Pipelines	0	0.00
	Subtotal		0.40
Electrical Power	Facilities	16	1,724.80
	Subtotal		1,724.80
Communication	Facilities	12	1.20
	Subtotal		1.20
	Total		3,343.60

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	500YearProbabilisticEvent
Type of Earthquake	Probabilistic
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	500.00
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	8.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Building Damage

HAZUS estimates that about 3,382 buildings will be at least moderately damaged. This is over 1.00 % of the total number of buildings in the region. There are an estimated 40 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 3 below summaries the expected damage by general occupancy for the buildings in the region. Table 4 summaries the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	858	0.33	59	0.57	29	0.98	5	1.24	0	0.83
Commercial	14,764	5.72	1,103	10.70	488	16.76	92	21.46	7	17.46
Education	488	0.19	39	0.38	18	0.62	3	0.72	0	0.93
Government	354	0.14	30	0.29	15	0.52	3	0.59	0	0.88
Industrial	4,230	1.64	303	2.94	142	4.88	26	6.12	2	3.95
Other Residential	33,392	12.93	1,808	17.55	646	22.18	77	18.03	8	18.61
Religion	1,441	0.56	102	0.99	47	1.62	9	2.11	1	2.16
Single Family	202,664	78.49	6,858	66.58	1,528	52.44	213	49.75	22	55.18
Total	**258,191**		**10,301**		**2,914**		**428**		**40**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	208,656	80.81	5800	56.31	694	23.83	37	8.75	0	0.15
Steel	6,746	2.61	484	4.70	268	9.20	49	11.51	2	4.05
Concrete	1,717	0.66	103	1.00	39	1.34	4	0.98	0	0.26
Precast	1,687	0.65	108	1.05	82	2.80	19	4.50	0	0.68
RM	975	0.38	47	0.46	31	1.05	5	1.24	0	0.03
URM	34,533	13.38	3263	31.67	1,550	53.20	301	70.29	38	94.22
MH	3,877	1.50	496	4.81	250	8.58	12	2.73	0	0.60
Total	**258,191**		**10,301**		**2,914**		**428**		**40**	

*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 3,596 hospital beds available for use. On the day of the earthquake, the model estimates that only 3,144 hospital beds (87.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 94.00% of the beds will be back in service. By 30 days, 99.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	15	0	0	15
Schools	271	0	0	271
EOCs	0	0	0	0
PoliceStations	32	0	0	32
FireStations	25	0	0	25

Transportation and Utility Lifeline Damage

Table 6 provides damage estimates for the transportation system.

Table 6: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	336	0	0	336	336
	Bridges	375	0	0	375	375
	Tunnels	2	0	0	2	2
Railways	Segments	143	0	0	143	143
	Bridges	15	0	0	15	15
	Tunnels	0	0	0	0	0
	Facilities	17	0	0	17	17
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	3	0	0	3	3
Ferry	Facilities	0	0	0	0	0
Port	Facilities	37	0	0	37	37
Airport	Facilities	2	0	0	2	2
	Runways	5	0	0	5	5

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	7	0	0	7	7
Waste Water	18	0	0	18	18
Natural Gas	1	0	0	1	1
Oil Systems	4	0	0	4	4
Electrical Power	16	0	0	16	16
Communication	12	0	0	12	12

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	5,322	13	3
Waste Water	3,193	10	3
Natural Gas	2,129	11	3
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	287,012	0	0	0	0	0
Electric Power		0	0	0	0	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 10 ignitions that will burn about 0.08 sq. mi 0.02 % of the region's total area.) The model also estimates that the fires will displace about 149 people and burn about 11 (millions of dollars) of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.160 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 64.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 6,440 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 200 households to be displaced due to the earthquake. Of these, 145 people (out of a total population of 693,604) will seek temporary shelter in public shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	2	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	1	0	0	0
	Industrial	1	0	0	0
	Other-Residential	23	3	0	1
	Single Family	38	5	0	1
	Total	**65**	**9**	**1**	**2**
2 PM	Commercial	98	15	1	3
	Commuting	0	0	0	0
	Educational	16	2	0	0
	Hotels	0	0	0	0
	Industrial	8	1	0	0
	Other-Residential	5	1	0	0
	Single Family	9	1	0	0
	Total	**136**	**20**	**2**	**4**
5 PM	Commercial	61	9	1	2
	Commuting	0	0	0	0
	Educational	2	0	0	0
	Hotels	0	0	0	0
	Industrial	5	1	0	0
	Other-Residential	9	1	0	0
	Single Family	15	2	0	0
	Total	**93**	**14**	**2**	**2**

Economic Loss

The total economic loss estimated for the earthquake is 346.73 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 324.29 (millions of dollars); 34 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 35 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Loses							
	Wage	0.00	0.90	22.69	1.19	2.21	26.99
	Capital-Related	0.00	0.39	20.55	0.73	0.47	22.14
	Rental	2.46	4.30	13.64	0.54	0.80	21.74
	Relocation	8.86	2.94	20.23	2.52	6.35	40.89
	Subtotal	**11.32**	**8.53**	**77.10**	**4.98**	**9.82**	**111.76**
Capital Stock Loses							
	Structural	14.85	5.92	21.72	5.65	4.76	52.91
	Non_Structural	41.45	19.92	37.12	9.69	10.10	118.28
	Content	9.07	3.87	16.01	6.10	4.44	39.50
	Inventory	0.00	0.00	0.40	1.42	0.03	1.85
	Subtotal	**65.37**	**29.71**	**75.26**	**22.86**	**19.33**	**212.53**
	Total	**76.70**	**38.23**	**152.36**	**27.85**	**29.15**	**324.29**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

HAZUS estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 14 presents the results of the region for the given earthquake.

Table 12: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	3,626.41	$0.00	0.00
	Bridges	1,035.21	$1.03	0.10
	Tunnels	2.86	$0.00	0.00
	Subtotal	**4664.50**	**1.00**	
Railways	Segments	208.54	$0.00	0.00
	Bridges	1.73	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	45.27	$1.13	2.50
	Subtotal	**255.50**	**1.10**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	3.20	$0.08	2.41
	Subtotal	**3.20**	**0.10**	
Ferry	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Port	Facilities	73.89	$3.76	5.09
	Subtotal	**73.90**	**3.80**	
Airport	Facilities	21.30	$0.28	1.33
	Runways	189.82	$0.00	0.00
	Subtotal	**211.10**	**0.30**	
	Total	**5208.20**	**6.30**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	228.40	$1.54	0.68
	Distribution Lines	106.40	$0.06	0.05
	Subtotal	**334.89**	**$1.60**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	1,174.80	$4.74	0.40
	Distribution Lines	63.90	$0.05	0.07
	Subtotal	**1,238.69**	**$4.78**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.10	$0.00	0.07
	Distribution Lines	42.60	$0.05	0.11
	Subtotal	**43.65**	**$0.05**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.40	$0.00	0.69
	Subtotal	**0.39**	**$0.00**	
Electrical Power	Facilities	1,724.80	$9.71	0.56
	Subtotal	**1,724.80**	**$9.71**	
Communication	Facilities	1.20	$0.01	0.49
	Subtotal	**1.18**	**$0.01**	
	Total	**3,343.59**	**$16.15**	

Table 14. Indirect Economic Impact with outside aid
(Employment as # of people and Income in millions of $)

LOSS		Total	%
First Year			
	Employment Impact	558	0.18
	Income Impact	0	0.00
Second Year			
	Employment Impact	232	0.08
	Income Impact	(5)	-0.04
Third Year			
	Employment Impact	6	0.00
	Income Impact	(8)	-0.06
Fourth Year			
	Employment Impact	0	0.00
	Income Impact	(8)	-0.06
Fifth Year			
	Employment Impact	0	0.00
	Income Impact	(8)	-0.06
Years 6 to 15			
	Employment Impact	0	0.00
	Income Impact	(8)	-0.06

Appendix A: County Listing for the Region

Jefferson, KY

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
Kentucky	Jefferson	693,604	45,426	19,812	65,238
Total State		**693,604**	**45,426**	**19,812**	**65,238**
Total Region		**693,604**	**45,426**	**19,812**	**65,238**

Study Region new : JeffersonCountyEarthquake

Hazard Scenario : 500YearProbabilisticEvent